



**Celebration  
of  
100 Years  
of**



**GEBCO**

*General Bathymetric Chart of the Oceans*



**Conference**

**“Charting the Secret World  
of the Ocean Floor.  
The GEBCO Project 1903-2003”**

**14 – 16 April 2003  
Monaco**

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## BATHYMETRIC REQUIREMENTS FOR FISHERIES RESEARCH

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### **Executive Summary**

Knowledge of bottom topography plays a key role in fisheries research studies directed at understanding demersal fish distributions, behaviour, and abundance and in assessing habitat. Methods of observations often include underwater acoustics that can in turn guide various capture operations of target species. However, bottom topography may impose severe limits on acoustic detection and assessment of fishes found in areas of high relief and steep slope. Habitat characteristics of different demersal species from the Chilean coast are used as example and results from two studies conducted on Widow rockfish (*Sebastes entomelas*) along the west coast of Canada illustrate the importance of having adequate understanding of bottom structures to correctly interpret acoustic observations. Examples are given where acoustic returns from sidelobe detection of bottom lead to echoes that appear as fish schools. The need for careful interpretation of echo returns by fishers and researchers are discussed. New methods to generate a representative 3D model of the bottom surface that can assist in near-boundary fish discrimination are shown. Images provide greater insight to echo source and highlight some of the difficulties associated with classifying acoustic sign. It is here emphasise the importance of good bathymetric knowledge to optimise survey design with regards to minimising sidelobe interference and reducing acoustic shadow zones.

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## CHRONOLOGY OF THE MAIN EVENTS RELATED TO THE ORIGINS, AND THE FIRST AND SECOND EDITIONS OF *LA CARTE GENERALE BATHYMETRIQUE DES OCEANS*

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Soundings and contour lines appear in the European charts during the 16th century. After the publication of a chart of the North Atlantic by M.F. MAURY (1853), bathymetric charts become more frequent, particularly in the oceanographic expeditions reports. Due to the lack of an international agreement, nomenclature and terminology are anarchic. Consequently, the 7th International Geographic Congress (Berlin, 1899) nominates a Commission on suboceanic nomenclature, also responsible for the publication of a general bathymetric chart. It convenes in Wiesbaden (April 15-16, 1903), Prince ALBERT I of Monaco in the chair, and adopts the characteristics defined in a memorandum by J. THOULET. The 24 sheets of *Carte générale bathymétrique des océans*, printed in Paris in 1905, hastily prepared, are harshly criticised by E. de MARGERIE. Immediately Prince ALBERT decides that a new edition will be made for which a second commission convenes in Monaco (1910). The second edition is printed from 1912 to 1931 with contour lines of the terrestrial relief and a revised nomenclature. The use of sonic and ultrasonic devices increases tremendously the amount of data. The responsibility of the Chart is then transferred to an international organisation : the International Hydrographic Bureau.

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# CONTRIBUTION OF MULTIBEAM BATHYMETRY TO UNDERSTANDING THE PROCESSES THAT SHAPE MID-OCEAN RIDGES

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## **Abstract**

With the emergence in the 1980's of multibeam bathymetric systems, comprehensive two-dimensional maps of the seafloor became available that changed our view of the mid-ocean ridges. Multibeam bathymetry reveals a fine-scale segmentation of the ridge axis, with ridge offsets as small as a few hundred meters. Ridge segments are 10-100km long and generally correspond with individual volcanic systems. While the morphology of the ridge axis depends primarily on spreading rates, it also varies predictably from the center to the ends of a ridge segment and with local supply of magma. Discordant features on the ridge flanks provide a continuous record of the tectonic evolution of the mid-ocean ridges and reveal that the plate boundary is commonly reorganizing in response to minor changes in plate motion and variations in the thermal structure of the lithosphere. Emerging deep submergence technologies now provide microbathymetric maps with a vertical resolution of a few cm, sufficient to accurately map individual lava flows, eruptive vents, fissures, and faults. A strategy of repeating microbathymetric surveys may offer the potential to precisely characterize seafloor spreading events.

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## **KNOWLEDGE OF THE DEEP OCEAN BY THE END OF THE 19TH CENTURY, LEADING UP TO THE DECISION IN 1899 TO COMPILE A WORLD SERIES OF BATHYMETRIC CHARTS**

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### **Summary**

Though remaining primitive by today's standards, and the degree of coverage achieved very limited, given the huge scale of the oceans, advances in the techniques of deep-sea sounding during the second half of the 19th century enabled scientists, geographers and surveyors to begin to obtain an outline view of the topography and nature of the deep ocean floor, and the kind of formations existing there and their distribution. It was a tribute to the success of their endeavours that by 1899 the need was being felt to systematize the terminology and nomenclature of ocean topography, and to put this work and the collating and charting of data on ocean depths on an international footing.

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## **BATHYMETRY AND OCEAN CIRCULATION**

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### **Executive Summary**

Bathymetry influences ocean circulation in several ways. First, it steers large-scale ocean circulation: even relatively small ridges on the sea floor can influence the direction of major ocean currents. In the deep ocean, ridges serve as solid barriers separating bottom waters in adjacent ocean basins. Gaps in bathymetry associated with fracture zones play an important role in determining how much water can pass between ocean basins and where these processes can occur. Second, small-scale bathymetric features also influence ocean circulation. When ocean currents pass over rough sea floor, energy is converted from horizontal flow into vertically propagating waves. This can result in elevated levels of vertical mixing over rough sea floor topography. Finally, ocean circulation and climate models are sensitive to the accuracy and resolution of the large-scale bathymetry that they resolve and to the mixing parameterizations for processes that they do not resolve. In the next ten years, model resolutions are expected to increase, and the importance of having accurate high-wavenumber bathymetry is expected to become increasingly acute.

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# THE ROLE OF BATHYMETRY IN INTERNATIONAL MARITIME LAW AND IN THE PROVISIONS OF THE UN CONVENTION ON THE LAW OF THE SEA

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## **Executive Summary**

For hundreds of years hydrographers have conducted bathymetric surveys on which to base the compilation of nautical charts and publications. These surveys were composite surveys in that consideration was also given to geographical and geological features, climatic and weather conditions and in fact anything that could impact on the safety of navigation of vessels. This service changed as technology changed and today the most sophisticated surveying, positioning and compiling systems are available to the hydrographer. As a result his role has changed to degree that he has data that can be put to a multitude of uses. While bathymetry is still the primary basis of nautical charting in all its forms, the coming into force of the United Nations Convention on the Law of the Sea (1982) has highlighted the importance of bathymetry to the many conditions and provisions contained in the Articles of this Convention. This paper attempts to highlight this importance and to draw attention to the arbitrary use of bathymetric data without reference to its meta-data.

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## PRINCIPLES AND APPLICATIONS OF OCEAN FEATURE NOMENCLATURE

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### **Abstract**

Undersea feature naming, meeting the requirements of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC, of UNESCO), is taken care by the GEBCO Sub-Committee on Undersea Feature Names (SCUFN). GEBCO (General Bathymetric Chart of the Oceans) is a joint IHO-IOC ocean mapping project for the world ocean. SCUFN's mandate includes defining the nomenclature of ocean bottom features, e.g. seamounts, ridges or fracture zones, and attributing names to newly identified, or unnamed, features lying in international waters. Two IHO-IOC publications are related to SCUFN's work: B-6 "Standardisation of Undersea Feature Names" and B-8 "Gazetteer of Undersea Feature Names". This paper describes the IHO-IOC standardisation work on undersea feature naming.

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## COMMERCIAL DRIVERS FOR IMPROVED OCEAN FLOOR CHARTS

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### Abstract

Over 40% of the 800+ multibeam echo-sounders world-wide are used for commercial surveys. These systems, as well as towed swath bathymetric side-scan sonar systems, have special requirements when used in deep water (>500 meters water depth) since they are generally surveying in preparation for installations such as cables and pipelines that will actually lie on the seabed. Future requirements for these surveys will be more rigorous as oil and gas development goes into water depths exceeding 2,000 meters, and as telecommunications cables must be buried in deeper water, often as a requirement for installation permits. These applications require one-meter bathymetry (0.05% of water depth in 2,000 meters) and precise navigation, which can only be achieved by deep towed sonar systems and eventually, when cost-effective, by AUVs. In the near future, commercial surveys will be covering around one million square kilometers per year, acquiring data that exceed International Hydrographic Organization standards. These data are being placed into integrated GIS databases, which will replace paper charts and reports, greatly improving the access and functionality of commercial survey information. The first multibeam echo-sounders were introduced for non-military use about 20 years ago. Since then the use of these systems has proliferated and the technology has improved to provide seabed maps with unprecedented accuracy and swath coverage. The purpose of this paper is to show the large number of swath bathymetry systems presently engaged in commercial surveys of the world's seafloor, to describe the types of surveys that are required for commercial purposes, and to demonstrate technological trends and mapping requirements for future surveys.

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## INTO THE DIGITAL AGE – THE GEBCO DIGITAL ATLAS

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### **Summary**

For almost two decades (1984-2003), the technical focus for the development of GEBCO has been provided through its Sub-Committee on Digital Bathymetry (SCDB). During the period 1984-93, the Sub-Committee's activities were centred primarily on the digitisation of the GEBCO 5th Edition and the establishment of an international database of digital echo-soundings. Thereafter, the focus switched to considering how digital techniques might be exploited to enhance and develop GEBCO. Particular attention was paid to the updating of the GEBCO contours and the creation of the GEBCO bathymetric grid. The paper reviews GEBCO's activities in the digital field, starting with the introduction of digital techniques in the 1980s and culminating with the release of the Centenary Edition of the GEBCO Digital Atlas in April 2003. An extended version of this paper, complete with figures and bibliography, may be found in the GEBCO Centenary Volume.

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## **TRANSFER OF RESPONSIBILITIES TO THE IHB AND DEVELOPMENT AND PUBLICATION OF THE 3RD AND 4TH EDITIONS**

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### **Summary**

This paper describes the development of the Third and Fourth Editions of GEBCO, from the point at which the work was passed from the Cabinet Scientifique of HSH Prince Albert I to the International Hydrographic Bureau. It was a period of significant turmoil and difficulty, with major changes in hydrographic technology, major political upheavals and a shortage of resources. There was also an ongoing debate on the scientific merit of the programme and whether the maps satisfied the needs of the scientific community. Although the Third Edition took a very long time to complete and the Fourth Edition was never completed, the author notes that to keep the data base going at all was a significant achievement of those involved in its management.

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## THE IMPACT ON OCEAN MAPPING OF THE POST WAR REVOLUTION IN MARINE GEOLOGY AND THE WORK OF SCOR WORKING GROUP 41

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### **Abstract**

Following the second world war, marine geology expanded rapidly due to the wide variety of new techniques that were available for studying the ocean floor. This resulted in the development of new understanding of the mechanisms and processes by which it was created, and in the revolutionary hypothesis of plate tectonics. Geoscientists needed detailed bathymetric charts on which to base their research, and found that the GEBCO charts had failed to utilise these new ideas. As a result the demand for the 3rd and 4th Edition charts nearly ceased. Prompted by the LEPOR report of IOC in 1968, SCOR set up Working Group 41 to review existing series of world charts and to recommend how to address the geoscientists' needs. The recommendations of the SCOR WG 41 led to the reorganisation of GEBCO, which became a joint activity of oceanographers and hydrographers, and to the initiation of the successful 5th Edition of GEBCO.

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# THE IMPACT OF OCEAN BOTTOM MORPHOLOGY ON THE MODELLING OF THE LONG GRAVITY WAVES, FROM TIDES AND TSUNAMI TO CLIMATE

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## **Abstract**

Ocean basin morphology is a major controlling parameter of the ocean dynamics. We address here its impact on long gravity waves: tsunamis, storm surges and tides. The deterministic character of the tides allows one to easily illustrate how modelling of long gravity wave in the ocean is dependant upon the knowledge of the shape and depth of the ocean basins, and on the slope of seamounts, mid ocean ridges and continental shelf breaks. A few examples are given. The first one is the impact of inaccuracies in the bathymetry on wave propagation at basin scale (the North Atlantic). The second one shows the global dependency of the solutions (the remote effect of the resolution of the tides under the Weddell Sea permanent ice shelf). The third one illustrates the trapping of energy by the continental slopes above the critical latitudes (the diurnal tides over the Yermak plateau). Particular focus is given on the importance of the energy transfer from barotropic tides to baroclinic internal waves. This transfer is taking place over seamounts, mid ocean ridges and at the shelf breaks, closely dependent upon the slope of the bathymetry. This energy transfer to internal wave could play a role on the deep ocean mixing, contributing to the maintenance of the thermohaline circulation, and hence impacting the climate of the earth.

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## **THE INTERNATIONAL BATHYMETRIC CHART OF THE ARCTIC OCEAN (IBCAO) - A NEW DIRECTION FOR OCEAN MAPMAKING**

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### **Abstract**

The project to develop the International Bathymetric Chart of the Arctic Ocean (IBCAO) featured innovations that could be usefully applied to the development of future editions of GEBCO and associated digital products. These innovations include: the use of digital data and methodologies in virtually all stages of the operation; the establishment of a single team to work across the entire Arctic region; and liberal policies for the public release of selected data products and images. By emulating some of these practices and through judicious marketing of the resulting outputs, GEBCO may be able to attract a wider range of users while generating revenue that would support future operations.

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## FRONTIERS IN SEA FLOOR MAPPING AND VISUALIZATION

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### **ABSTRACT**

We have seen remarkable and concomitant advances in sonar technology, positioning capabilities, and computer processing power that have revolutionized the way we map, image and explore the seafloor. Future developments must involve all aspects of the “seafloor mapping system” including, the sonars, the ancillary sensors (motion sensors, positioning systems, and sound speed sensors), the platforms upon which they are mounted, and the products that are produced. Current trends in sonar development involve the use of innovative new transducer materials, and the application of sophisticated processing techniques including focusing algorithms. Future developments will inevitably involve “hybrid”, phase-comparison/beam-forming sonars, the development of broad-band “chirp” multibeam sonars and perhaps synthetic aperture multibeam sonars. Our inability to monitor the fine-scale spatial and temporal variability of the sound speed structure of the water column is a limiting factor in our ability to accurately map the seafloor; improvements in this area will involve continuous monitoring devices as well as improved models and perhaps tomography. ROV’s and particularly AUV’s will become more and more important as platforms for seafloor mapping system. We will also see great changes in the products produced from seafloor mapping and the processing necessary to create them. New processing algorithms are being developed that take advantage of the density of multibeam sonar data and use statistically robust techniques to “clean” massive data sets very rapidly. We are also exploring a range of approaches to use multibeam sonar bathymetry and imagery to extract quantitative information about seafloor properties, including those relevant to fisheries habitat. The density of these data also enable the use of interactive 3-D visualization and exploration tools specifically designed to facilitate the interpretation and analysis of very large, complex, multicomponent spatial data sets. If properly georeferenced and treated, these complex data sets can be presented in a natural and intuitive manner that allows the simple integration and fusion of multiple components without compromise to the quantitative aspects of the data and opens up new worlds of interactive exploration to a multitude of users. The challenge for the future of GEBCO is to provide information in a form that is appropriate for these new approaches to analyzing and interpreting seafloor data.

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## **A LOOK TO THE FUTURE; OCEAN MAPPING IN THE TWENTY FIRST CENTURY**

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### **Executive Summary**

This paper attempts to position the GEBCO organization in time, that is, in the flow of events impacting the partnering organizations and the changes in technology that will influence GEBCO in the next few years. Against this backdrop, the paper explores the concept of producing a new edition of GEBCO and concludes that there will not be a “sixth edition” with the same meaning that earlier editions had. Rather, sounding data from navigational hydrography, contours from the IOC's regional bathymetric maps, multibeam data from the deep ocean, and altimetry –derived bathymetric information will be contributed to a digital data base from which all marine science can draw seafloor morphologic information.

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## **BUILDING THE FIFTH EDITION: AN EXERCISE IN COOPERATION**

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### **Executive Summary**

This paper describes how a combination of forces and a combination of willing people from a number of disciplines achieved the creation of the first bathymetric map of the world ocean made up from depth data supplied by all nations and corrected to a known standard of quality which was clearly shown to users of the maps.

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## INTERPOLATION AND CONTOURING OF SPARSE SOUNDING DATA

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### Executive Summary

The back of the moon and the surfaces of most planets of our solar system are better mapped than the seafloor topography of our own planet. There are several reasons for this. The main reason is that the seafloor is invisible and thus sonar signals must be used to pass through water as the medium in this case and measure the depths of the oceans. Another reason is that the inhospitable polar regions of the Earth can only be safely visited by ships during the short summer seasons. Thus, large regions of the northern and southern oceans remain "white spots" and their topography is widely unknown. At low latitudes expeditions can be performed year-round, sounding data can be recorded "en-route" and used for ocean mapping. Digital Terrain Models (DTM) are widely used by many different disciplines in a broad spectrum of applications. Thus, a major task is to develop techniques to determine DTMs on the basis of primary soundings, existing contour charts or terrain models. Auxiliary information for the creation of a DTM can be obtained from satellite radar altimetry data. Variations of the measured sea surface heights over the geoid or of the gravity values can be related to changes in the seafloor topography or to density variations in the Earth's upper crust. The modelling approach presented in this paper has been used at AWI for several years. Results from three mapping projects in the Arctic and Antarctic are presented here. They document the validity of the chosen contouring approach in areas of sparse data.

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## OCEANOGRAPHY JOINS HYDROGRAPHY

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### **Abstract**

The 5th Edition of the GEBCO (and subsequent developments) has been the result of close and successful collaboration between the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. However, this paper shows that although there has been close working collaboration between the Hydrographic and Oceanographic communities over many years, and the International Hydrographic Bureau (IHB) clearly recognised this from its foundation in the early 1920s, the scientific input needed to develop a product that meets the needs of oceanographers did not become available until the IOC was established some 40 years later, and it was possible to set up a joint project with clear responsibilities identified for the two closely linked but disparate communities.

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# **LEADLINE TO MULTIBEAM, SEXTANT TO GPS & CROW QUILL TO COMPUTER: BATHYMETRIC DATA COLLECTION, COMPILATION, ARCHIVING, AND DISTRIBUTION IN THE PAST CENTURY**

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## **Abstract**

GEBCO has been publishing the bathymetry of the world's oceans for 100 years and, in that century, there have been revolutionary changes to defy even the retrospective imagination. From laborious sounding of the deep sea by lowering a weighted wire and positioning with celestial navigation with an accuracy of less than a nautical mile, the art and science of bathymetry has become orders of magnitude more accurate, more efficient, and more productive. Today's soundings are accurate to a few meters vertically and horizontally. Early progress was driven by engineering technology while later progress was detonated by computer technology, which has given us an exponentially growing capability, providing millions of times more computational power since the early 1970's. That capability has influenced all phases of bathymetric data management: collecting the soundings, compiling the data for analysis, archiving the data, and distributing the data and derived products. Our perception and model of the seafloor has likewise increased in accuracy and resolution in an exponential fashion, although even today, only of the order of 10% of the seafloor has been measured with direct echo-sounding. The task of GEBCO is to ride this growing wave of data, capability, and technology to continue producing the authoritative portrayal of the 70% of Earth's surface beneath the seas.

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## **ON THE USE OF SATELLITE ALTIMETER DATA TO ENHANCE BATHYMETRIC INTERPRETATIONS IN AREAS OF SPARSE SOUNDINGS**

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### **Executive Summary**

It is an honor to be included in this celebration and to be scheduled in the future-looking section of the Centenary. Satellite altimetry is an indirect mapping technique that yields gravity anomalies that may be partially correlated with bathymetry under certain geologic conditions. Even under optimal conditions, the ultimate resolution of the technique is bounded by physical laws; resolvable features must have a width and length in plan view as large as, or larger than, the mean depth of the surrounding sea floor. Currently available data have not yet achieved this resolution, and are in fact two to three times worse in resolved length (four to nine times worse in resolved area). I am optimistic about the prospects of improving this resolution, first by reprocessing existing data, and later with a new dedicated altimeter mission. The main virtue of satellite remote sensing is globally uniform data quality at low cost, something shipboard surveys cannot provide. Therefore I believe that satellite reconnaissance of ocean floor structure will continue to play an important role in ocean mapping. I hope I may also have the pleasure of a continuing role in GEBCO.

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## **GEODESIC DATUM CONVERSION IN JAPAN; From Tokyo Datum to WGS84**

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# **TECHNICAL DEVELOPMENTS IN DEPTH MEASUREMENT TECHNIQUES AND POSITION DETERMINATION FROM 1960 TO 1980**

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## **Executive Summary**

In this paper we describe the evolution during these two decades from simple single-beam echo-sounders using horizontal sextant fixing (near shore), and celestial sextant positioning interpolated by dead reckoning (offshore) to (a) (For depth measurement techniques) sidescan sonar, digital echo-sounders, the first (classified) SASS and Seabeam multibeam systems, and early satellite altimetry, and (b) (For positioning determination) a plethora of short and long range radio positioning systems, the Transit satellite positioning system, the early designs for GPS, long and short baseline acoustic systems, and (c) How these developments have since impacted the data available to GEBCO

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**GEBCO Centenary Conference (2003)**  
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**A Review**

**The Celebration of 100 Years of GEBCO**

At the 7th International Geographic Conference in Berlin in 1899 a proposal was made for the development of an international agreement on nomenclature and systematic terminology for sub-ocean relief features. A Commission was set up to process this matter, but it was also charged with the preparation of a bathymetric map of the oceans.

The Commission did not meet until April 1903 when its seven members assembled in Wiesbaden under the chairmanship of Prince Albert of Monaco, the great grandfather of Prince Rainier III, the present ruler. No funds were available for the proposed map so Prince Albert agreed to organise and finance a *General Bathymetric Chart of the Oceans* and thus GEBCO was founded in 1903.

The Centenary of GEBCO was duly celebrated in the Principality of Monaco, on 14th to 16th April this year, by a gathering of about two hundred hydrographers and oceanographers from many maritime nations.

The core of the celebrations was a three-day conference, in a new small theatre known as the Salle des Variétés, opened by Prince Albert, son of Prince Rainier. Sir Anthony Laughton, Chairman of the GEBCO Guiding Committee since 1985, welcomed twenty four speakers.

Jacqueline Carpine-Lancre, former Librarian at the Musée Océanographique in Monaco Ville, set the ball rolling with a magnificent twenty minute discourse concerning the chronology of the main events relating to the origins, and the 1st and 2nd editions of GEBCO. She spoke in French, the only speaker to do so, whilst her instantaneous English interpreter was quite excellent.

It is perhaps invidious to mention only a few of the speakers, but the presentation by Desmond Scott entitled *A Change in Direction* must be noted. As Secretary to the International Oceanographic Commission in the early 1970s he was deeply involved with the setting up of a joint IOC-IHO Guiding Committee which brought oceanographers and hydrographers together with five members from each of these two bodies serving together. Desmond Scott became Secretary of this Committee and has been closely associated with GEBCO ever since.

It was the Guiding Committee which planned the 5th edition of this great chart which, thanks to the Canadian Hydrographic Service printing the 24 sheets on 1/10 million, was ready for presentation at the 1982 International Hydrographic Conference. Soon after this the Guiding Committee decided that the printed sheets of this 5th edition should be digitised and published as the *GEBCO Digital Atlas* (GDA). Two speakers, David Monahan of the Canadian Hydrographic Service, and Meirion Jones, Director of the British Oceanographic Data Centre, described how the GDA will be constantly updated, whilst others spoke of the benefits that will accrue for those involved in commercial activities such as cable laying, fisheries and deep-sea drilling.

Dr Michael Loughridge, recently retired Director of the US National Geophysical Data Center, and for many years a member of the Guiding Committee, acted as Chairman throughout the Conference thus providing a sense of continuity. The use of laptop computers, by the majority of the speakers made for smooth running presentations; the days of 'next slide please', and the confusion which so often arose, are happily now in the past.

A significant part of the celebrations was the publication of *The History of GEBCO –1903-2003* a copy of which was presented to every delegate. Chapters are written by a dozen different authors who cover, in considerable detail, the whole story from how deep-sea soundings were obtained during the 19th century through to a description of the Digital Atlas. Excellent colour illustrations show how the sheets of the charts changed over the years.

The Directing Committee of the International Hydrographic Bureau, led by their President Admiral Maratas, gave a most enjoyable reception in their commodious conference room. From the present Bureau one can see across the harbour a luxury four-storey hotel rising on the site where the old Bureau stood for nearly seventy years.

On the second evening of the Conference the Government of Monaco gave a champagne reception for delegates in one of the exquisitely embellished rooms at the Hotel de Paris. It was good to be back in Monaco!

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